Permittivity measurement of sand and clay soil with a capacitive sensor

PERMITTIVITY MEASUREMENTS OF SOIL WITH A CAPACITIVE SENSOR

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ABSTRACT

The determination of permittivity of sand and clay soil over a wide frequency band can be useful in several applications. Fringing Capacitive sensors can be used to measure the real and imaginary part of the permittivity of materials in the RF and microwave frequency bands.

In this work the use of a commercial capacitive sensor has been exploited in order to characterize sand and clay soils with different water content. Liquid and granular materials are particular suited for this kind of sensor because the sensor can be dipped into the sample thus avoiding contact problems between the surface of the sensor and the material as for solid.

1 Permittivity determination: different methods

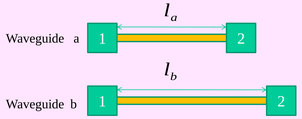
⇨ **FREQUENCY DOMAIN METHODS**

- **Open-Ended Coaxial Probe Technique**
- Cavity Perturbation Method
- **Transmission/Reflection Method**
  - **– Coaxial Line**
  - – Waveguide

⇨ **TIME DOMAIN METHODS**

- Time Domain Reflectometry (TDR)

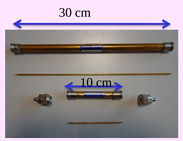
2 Transmission/Reflection: double-delay method [1]



S-parameters measurements ⇨ $\varepsilon(f)$

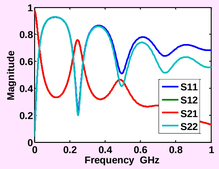
METHANOL

Coaxial airlines [2]

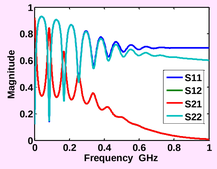


Outer radius 3.5mm
Inner radius 1.5mm

Short coaxial airline.



Long coaxial airline.

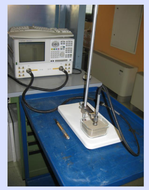


3 Open-ended coax probe (Agilent 85070D)

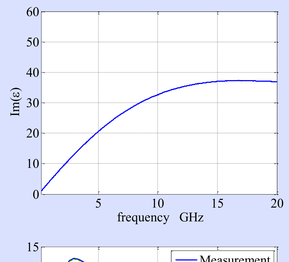
Frequency Range 200MHz to 20 GHz

Accuracy: Permittivity $\pm 5\%$

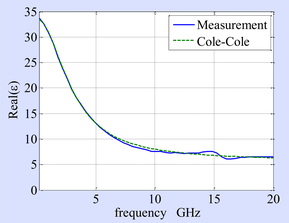
$\tan \partial = \pm 0.05$

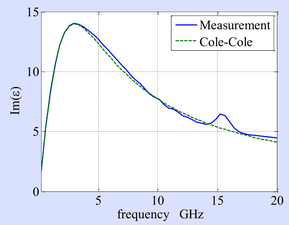


3a Reference cases: deionized water, methanol and ethanol



DEIONIZED WATER



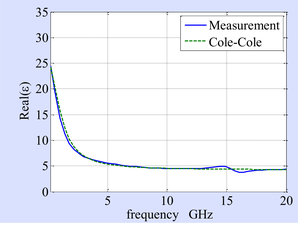


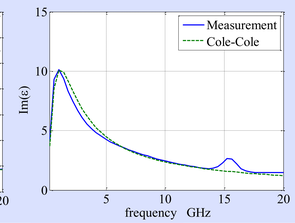
METHANOL

$\varepsilon_s = 33.64, \quad \varepsilon_\infty = 5.7$

$f_{rel} = 3.33e{-}10\ Hz$

$\alpha = 0$





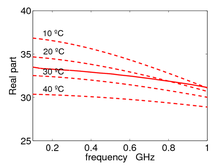
ETHANOL

$\varepsilon_s = 25.07, \quad \varepsilon_\infty = 4.2$

$f_{rel} = 8.98e{-}10\ Hz$

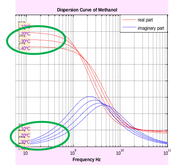
$\alpha = 0.015$

PERMITTIVITY – REAL PART

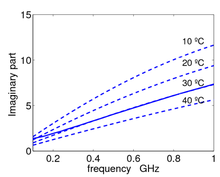


METHANOL

DISPERSION CURVE [3]



PERMITTIVITY – IMMAGINARY PART

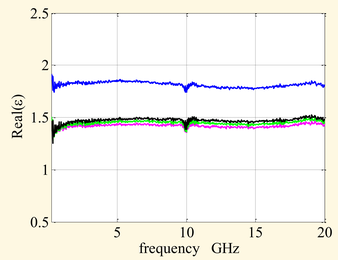


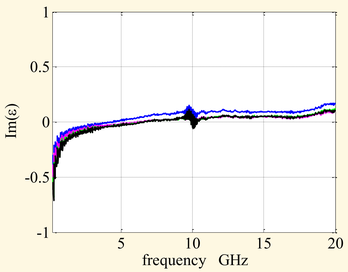
Our measurements
From [3]

Our measurements
From [3]

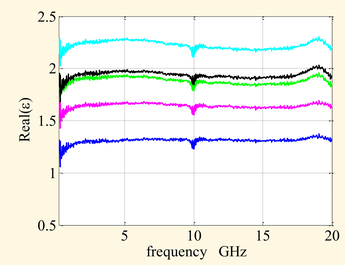
3b Results: sand and clay

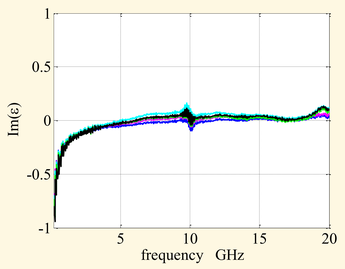
SAND





CLAY





CONCLUSIONS

Fringing Capacitive sensors can be used to measure the real and imaginary part of the permittivity of materials in the RF and microwave frequency bands.

This type of sensor is particularly suited for liquid whereas for semisolid materials the contact surface and the granulosity of the sample are critical.

Bibliography

[1] Rautio J.C., ``A de-embedding algorithm for electromagnetics". Int. Journal of Microwave and Millimeter-Wave Computer-Aided Engineering, 1(3):282-2S7, 1991.

[2] Savi P., Nyiazov U., Maio I.A., `` Complex Permittivity Determination from Measured Scattering Parameters of TEM Waveguides ". International Conference on Electromagnetics in Advanced Applications, Torino, September 12-17, 2011.

[3] Jordan B.P., Sheppardt R.J. and Szwarnowskit S.. `The dielectric properties of formamide, ethanediol and methanol", J. Phys. D: Appl. Phys.}, 11:695-701, 1978.